HYDRO STATICS

STRESSES ON THIN-WALLED PRESSURE VESSELS

Fluid Action on Surfaces

Stresses on thin-walled pressure vessels

Thin-walled Cylindrical Tank

The circumferential stress, also known as tangential stress, in a tank or pipe can be determined by applying the concept of fluid pressure against curved surfaces. The wall of a tank or pipe carrying fluid under pressure is subjected to tensile forces across its longitudinal and transverse sections.

Tangential Stress, σ_t (Circumferential Stress)

Consider the tank shown being subjected to an internal pressure p. The length of the tank is L perpendicular to the drawing and the wall thickness is t. Isolating the right half of the tank:

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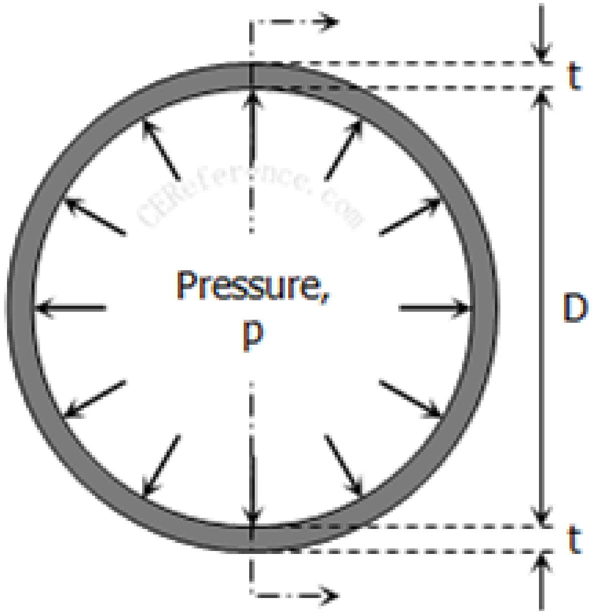
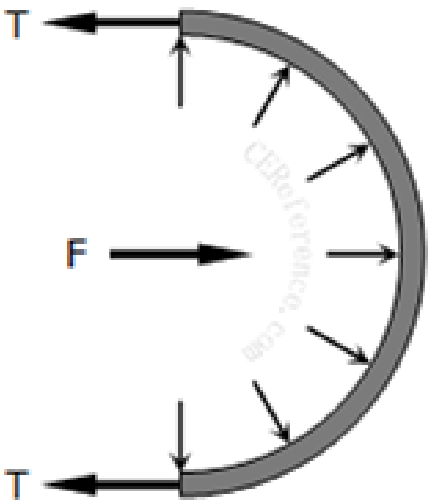
Tangential Stress, σ_t (Circumferential Stress)





$$2T = F$$

$$2(\sigma_t t L) = pDL$$

$$2t\sigma_t = pD$$

$$\sigma_t = \frac{pD}{2t}$$

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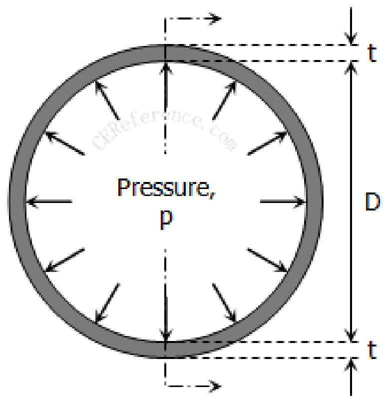
Longitudinal Stress, σ_l

At the end of the tank, the total stress $P_T = \sigma_l A_{end}$ should equal the total fluid force F at that end. Since the wall thickness t is so small compared to internal diameter D, the area A_{end} of the wall is close to πDt.



$$P_T = F$$

$$\sigma_l A_{end} = \pi A_i$$

$$\sigma_l(\pi Dt) = p(\tfrac{1}{4}\pi D^2)$$

$$t\sigma_l = \tfrac{1}{4}pD$$

$$\sigma_l = \frac{pD}{4t}$$

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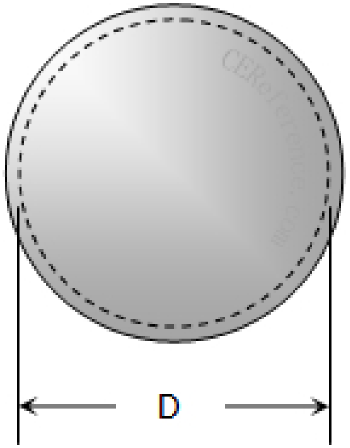
Spherical Shell

If a spherical tank of diameter D and thickness t contains gas under a pressure of p, the stress at the wall can be expressed as:



$$\sigma_l = \frac{pD}{4t}$$

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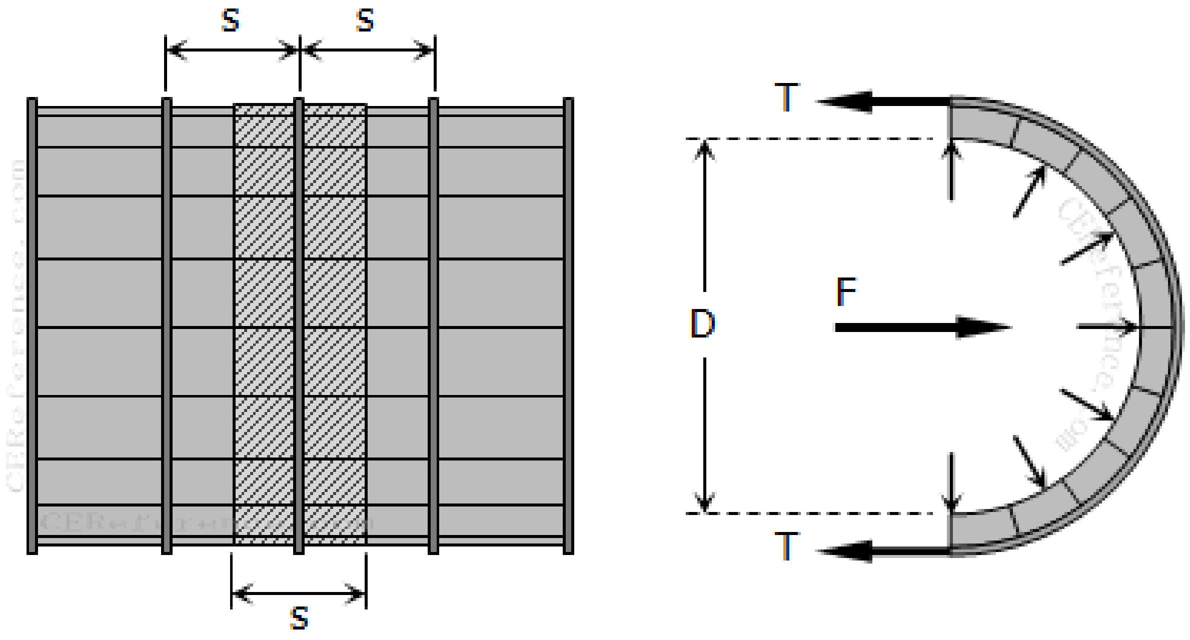
Stresses on thin-walled pressure vessels

Spacing of Hoops of Wood Stave Vessels

It is assumed that the wood will not resist tension, only the hoops will resist all the tensile stress caused by the internal pressure p.



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Stresses on thin-walled pressure vessels

Spacing of Hoops of Wood Stave Vessels

$$F = 2T$$

$$pDs = 2\sigma_t A_h$$

$$s = \frac{2\sigma_t A_h}{pD}$$

where

s = spacing of hoops

σ_t = allowable tensile stress of the hoop

A_h = cross-sectional area of the hoop

p = internal pressure in the vessel

D = internal diameter of the vessel

Fluid Action on Surfaces

Problem Set 9

Problem 1

Determine the stress at the walls of a 200 mm diameter pipe, 10 mm thick under a pressure of 150 m of water and submerged to a depth of 20 m in salt water.

$Ans: \sigma_t = 12.69\ MPa$

Problem Set 9

Problem 2

A wooden storage vat is 6 m in diameter and is filled with 7 m of oil (s = 0.8). The wood stave are bound by flat steel bands, 50 mm wide by 6 mm thick, whose allowable tensile stress is 110 MPa. What is the required spacing of the bands near the bottom of the vat, neglecting any initial stress?

$Ans: S = 200.23\ mm$

Problem Set 9

Problem 3

A thin-walled hallow sphere 3.5 m in diameter holds helium gas at 1700 kPa. Determine the minimum wall thickness of the sphere if its allowable stress is 60 MPa.

$Ans: t = 24.79\ mm$

Fluid Action on Surfaces

Problem Set 9

Problem 4

A vertical cylindrical tank is 2 m in diameter and 3 m high. Its sides are held in position by means of two steel hoops, one at the top and the other at the bottom. If the tank is filled with water to a depth of 2.1 m, determine the tensile stress in each hoop.

$Ans: T_{top} = 5.05\ kN,\ T_{bottom} = 16.58\ kN$

Fluid Action on Surfaces

Problem Set 9

Problem 5

A cylindrical tank with its axis vertical is 1 m in diameter and 3.6 m high. It is held together by two steel hoops, one at the top and the other at the bottom. Three liquids A, B, and C having specific gravities of 1, 2, and 3 respectively fill this tank, each having a depth of 1.2 m. On the surface of A there is atmospheric pressure. Find the tensile stress in each hoop if each has a cross-sectional area of 1250 $sq.mm$.

Ans: $T_{top} = 11.3\ MPa,\ T_{bottom} = 28.25\ MPa$